

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6A

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6A
Page Number : 29
Paragraph : Table 2.2
Comment : Is the thermally equivalent thickness for bridging
☐ two way a misprint? How can an in-place thickness
of 0.38" have an equivalent thickness of 0.6"?
Comment Reason : Possible error

Revision Suggestion : Insert correct value if an error has occurred.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6A

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR1-6A
Page Number : 17
Paragraph : Fig 2-2
Comment : A demonstration of the application of an unspecified
Monokote material is in progress.
How does this relate to the Cafco Blaze-Shield material?
Comment Reason : Unclear if this material is similar to the Blaze shield.

Revision Suggestion : Make comment if it is similar, or application techniques
are the same.

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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6A
Page Number : 21
Paragraph : Section 2.2.9. Para 2 & 3.
Comment : Qualitatively how weak was the SFRM from the samples made in the course of the investigation?
Comment Reason : It would help readers put the strength of the SFRM into context. Qualitative information like this would be useful in building up a picture of how it may have behaved on 9-11-2001

Revision Suggestion : Add comments about how easily dented or crushed the materials could be.

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Report Number : NCSTAR1-6A
Page Number : 31
Paragraph : Section 2.6.4/Para 4
Comment : Were the US Gypsum Co panels the same as those
used in the WTC towers? Or were they chosen as
typical materials so would be representative of those
used to insulate the core columns?
Comment Reason : Useful context.

Revision Suggestion : State why those gypsum panels were chosen.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6A
Page Number : 34
Paragraph : Section 2.7.2. Paragraph 2/Sentence 8
Comment : It is unclear how if 'the first test resulted in cohesive failure, the second test measured adhesive strength' -Could another cohesive failure not have occurred?
Comment Reason : Reason for the assumption is unclear.

Revision Suggestion : Please explain why this assumption is correct, or state that either adhesive or cohesive failure could have occurred.

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Report Number : NCSTAR1-6A
Page Number : 34

Paragraph : Paragraph 5/Sentence 2

Comment : The implications of the comment that 'two thirds of the specimens with the thicker SFRM had no adhesion to the coated steel plates' seems to have been underestimated. This implies that all the SFRM in the vicinity of the plane impact on WTC1 could have easily come off the bulk of the columns and some of the flat sections in the trusses.

Comment Reason : This seems to have been ignored in the flat plate calculation for acceleration required to cause debonding.

Revision Suggestion : Make more of the fact that large areas of SFRM could have been debonded before the time of the impact on WTC1 where the thicker SFRM had been applied to painted steelwork.

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Information Submitted on: 8/3/2005.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 39
Paragraph : Section 3.2.2, Paragraph 2/Sentences 1 and 2
Comment : While the average of the limited measurements made in 1994 may be 3/4", this is not the critical SFRM thickness.
As noted in NCSTAR 1-6A, the minimum observed SFRM thickness was 0.52 inches. This value, whether over the full length of a truss or in a localized area, would be the critical thickness.
Justification for assuming 3/4 inches has not been provided.
Applying 3/4" of SFRM could lead to misleading results regarding the actual performance of the WTC trusses as they were installed.
Comment Reason : Justification and clarification required.

Revision Suggestion : Include discussion and justification regarding the application of the average observed SFRM thickness rather than the minimum (critical) thickness.

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Report Number : NCSTAR1-6
Page Number : 55
Paragraph : Section 3.7
Comment : The summary does not specifically address the four purpose statements included in Section 3.1.2.

Comment Reason : The purpose statements should be specifically addressed in the conclusion in order to show how the purposes of the testing were achieved and to answer the questions asked in the purpose statements.

Revision Suggestion : Add specific discussion relating the testing results to the purpose statements of Section 3.1.2.

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 2
Paragraph : Section 1.2, Paragraph 1 including bullet points
Comment : The purpose statements listed here do not correspond with the purpose statements laid out in NCSTAR 1-6, Chapter 3.

Comment Reason : Purpose statements are inconsistent between this report and NCSTAR 1-6.

Revision Suggestion : Add a fourth bullet as follows:
"to determine whether there was an adequate technical basis for the original fireproofing specification"

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 3
Paragraph : Section 1.4, Paragraph 3/Sentences 1 and 2
Comment : The term "unconstrained" is used here but nowhere else in the report.

It is assumed that this implies "unrestrained," which is used elsewhere.

Comment Reason : Terminology should be kept consistent throughout the report in order to ensure clarity.

In this case, it should also correspond to the test standard

Revision Suggestion : Change two instances of "unconstrained" to "unrestrained"

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Report Number : NCSTAR1-6B
Page Number : 4
Paragraph : Section 1.4, Paragraph 5/Sentence 2
Comment : Given the variability in thickness of SFRM observed on the main trusses of WTC 2, how confident can NIST be that 3/8" is the average value for SFRM thickness on the bridging trusses?
Was variation of this SFRM thickness considered, and what would the impact be?
Comment Reason : Clarification needed.

Revision Suggestion : Add discussion regarding the confidence in the SFRM thickness value, and the possible impact of variability here.

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Report Number : NCSTAR1-6B
Page Number : 10
Paragraph : Section 4.1.5, Paragraph 2/Sentence 5
Comment : It is stated that the test assemblies were designed to AISC standards of 1989, while the AISC standard current when the WTC towers were designed was the 1963 version.
These versions differ significantly in some areas.
What is the rationale behind designing the assemblies to the 1989 standard?
Comment Reason : Clarification and justification needed.

Revision Suggestion : Clarification and justification needed. Provide discussion of and justification for designing the test assemblies to 1989 standards rather than 1963 standards.

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Report Number : NCSTAR1-6B
Page Number : 10
Paragraph : Section 4.1.5, Paragraph 2/Sentence 5
Comment : The 1989 AISC Specification for Structural Steel Buildings referenced here is not included in the References list in Chapter 7.
Comment Reason : Missing reference.

Revision Suggestion : Include full reference in Chapter 7.

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Report Number : NCSTAR1-6B
Page Number : 12
Paragraph : Section 4.2.3, Paragraph 1/Sentences 4 and 5
Comment : It is stated that the MIG welds used in fabricating the test assemblies were designed to meet 2001 AISC strength requirements. The replacement of SMA welds with MIG welds has not been technically justified. Also, it is unclear how the 2001 strength requirements compare to the strength requirements imposed on the original WTC design.
Comment Reason : Clarification and justification required.

Revision Suggestion : Provide technical justification for using MIG welds instead of SMA welds.
Provide comparison of 2001 weld strength standards with ~1963 weld strength standards.
Provide discussion of the impact of variation between the weld strength standards.

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Report Number : NCSTAR1-6B
Page Number : 12

Paragraph : Section 4.2.4, Paragraph 1/Sentence 5

Comment : The report does not state how it was determined that seaming the metal deck longitudinally would be acceptable given that the original deck in the WTC towers was not seamed in this way.

The strength of a seamed deck is not likely equivalent to an unseamed deck of the same span.

Failure of the seam, as was observed in the tests of Assembly 1 and Assembly 3, can lead to negative effects, such as spalling, more rapid heat transfer through the slab, and loss of support of the slab.

Comment Reason : The seamed metal deck does not necessarily represent the in-place conditions in the WTC towers.

Also, failure of the seams was observed in two of the 4 tests, and this effect could not have occurred in the original WTC assemblies.

Revision Suggestion : Provide justification for using seamed decking.

If possible, provide analysis of the impact of the seaming and discussion of the seam failures in Assemblies 1 and 3.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 19
Paragraph : Section 4.2.8, Paragraph 1/Sentence 1
Comment : BLAZE-SHIELD Type DC/F SFRM was used in the test assemblies, while the SFRM used in the WTC towers was Caico Type D.
There is no discussion regarding this deviation from the original design.
Comment Reason : Different SFRM materials can have different performance characteristics, including adherability during fire and fire protection performance.

Revision Suggestion : Provide data regarding composition and performance of both Caico Type D and BLAZE-SHIELD Type DC/F.
Provide justification for this substitution.
Discuss possible impacts of this substitution.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 28
Paragraph : Section 4.3.1, Table 4-3
Comment : A large variation between the compressive strengths of the concrete slabs for Assemblies 1 and 2 was observed but not discussed.
Also, additional water was added to Assembly 1 but not discussed.
These were intended to have an identical mix design, but ultimately were significantly different.

Comment Reason : Additional information needed.

Revision Suggestion : Provide additional information regarding the pouring and strength testing of Assemblies 1 and 2.
Provide discussion of the impact of the different compressive strength measurements.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 47
Paragraph : Chapter 5, Paragraph 1/Sentence 1
Comment : The introduction to Chapter 5 states that the tests were carried out in accordance with the 2000 version of ASTM E 119.
The 2000 version differs significantly from the 1961 version, for instance in terms of member restraint.
The use of the 2000 version is acceptable for determining the assembly performance that would currently be expected based on the standard test, however it is not appropriate for determining the performance that would have been expected of the assembly given the standard test of 1961.
Comment Reason : The use of the 2000 test standard may negate conclusions regarding what performance would have been predicted had the assembly been tested in the 1960's.

Revision Suggestion : Include a comparison of the 1961 and 2000 versions of ASTM E 119 and discuss whether or not the differences would lead to variations in the prediction of performance.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 99
Paragraph : Section 6.1.3, Paragraph 3/Sentence 5
Comment : Reference to Figure 5-50 is incorrect.
This should refer to Figure 5-53.
Comment Reason : Incorrect figure reference.

Revision Suggestion : Replace Figure 5-50 with 5-53

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6B
Page Number : 104
Paragraph : Section 6.2, Bullet 2
Comment : The bullet states that in the reduced-scale unrestrained test, the load was maintained for 3 1/2 h without collapsing.
Neither of the reduced-scale tests was conducted in the unrestrained condition.
We think this is referring to Test 3.
Comment Reason : Incorrect reference to test condition.

Revision Suggestion : Change "reduced-scale unrestrained test" to
"reduced-scale test with 3/4 inch thick spray-applied fire resistive material"

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Information Submitted on: 8/3/2005.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6C
Page Number : 72
Paragraph : paragraph 1 / sentences 1-5
Comment : There is only a small amount of written text describing the basis of the temperatures used for the truss model, particularly differential temperatures between elements and through the slab thickness
Comment Reason : The temperature regime used in this calculation is approximate and described as not being based on the fire analysis. As a result of the temperatures used, there are early failures of studs, straps and knuckles, with chord yielding. These are as a result of restraints and temperature differences between steel and slab. Although it may not be possible to cover all real fire scenarios in this analysis, it would be valuable to test the sensitivity of the results to variations in the assumptions regarding temperature variation through the slab with time, temperature variation between the truss chords and the slab, and between the upper and lower truss chords. This would take account of the likelihood that, in cases near impact zones, where all fire proofing was estimated to be lost, the upper chord may be cooler than the lower chord, due to thermal mass and contact with the slab. It would also affect the deflection pattern if higher temperatures on the lower chord result in further bowing.

Revision Suggestion : We recommend further discussion on the basis of the temperatures used for the truss model, particularly differential temperatures between elements and through the slab thickness.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6C
Page Number : 70
Paragraph : Section 5.4.3 sentence 1, Figure 5.26
Comment : Recommend assessing sensitivity of results to changes of assumed boundary conditions in the truss model.
Comment Reason : The boundary conditions for this analysis involved rigid fixity at the ends of columns above and below the truss modelled, and fixed support at the core. This would represent an upper bound on this stiffness, since in all real cases the storeys above will not represent a fixed support, but will form a spring restraint, and will also moving outwards in the case that several floors are being heated. Hence the boundary conditions that were assumed would tend to lead to an overestimate of forces pushing outward, and would change the inward forces as the floor sags into catenary action. This is a complex effect based on difference in stiffness, expansion and deflection. We note that the issue of inward and outward force transfers from floors to walls was one where some difficulties were found in achieving correlation of analysis with observed results. Hence it would be useful to explore this effect by testing sensitivity of the results to the variation of boundary conditions.

Revision Suggestion : Recommend assessing sensitivity of results to changes of assumed boundary conditions in the truss model.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6C
Page Number : 116
Paragraph : Section 5.58 Paragraph 1/Sentences 1-5
Comment : Further discussion and assessment needed of force transfers between floors and walls, in relation to the boundary conditions.
Comment Reason : It is noted that, as with the simplified truss models, the full floor models included rigid fixity of columns one storey above and below the floors modelled. This is an overestimate of actual restraint, and would be expected to change the calculated pulling and pushing forces between the floors and the walls. It would also change the deflection of the walls, and the time at which truss seat walk-off occurs, leading to collapse of a truss. It is understood and accepted that the boundary conditions for these single floor models cannot fully represent the true interactions across several floors, however further tests to explore bounds on this issue by testing less rigid boundaries would be beneficial, since they are critical in overall behaviour.
Revision Suggestion : Further discussion and assessment needed of force transfers between floors and walls, in relation to the boundary conditions.

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Report Number : NCSTAR1-6C
Page Number : 153

Paragraph : Section 5.5.17 Paragraph 2/Sentences 1-2

Comment : There appears to be no reason given for why pull-in forces were not observed as expected, and different between WTC1 and WTC2.

Comment Reason : The transfer of horizontal forces between floors and vertical structures is a critical interaction. If analysis is to be valid, the load paths and performance of the models needs to be understood and rationalised, to ensure that critical aspects of the performance have been captured.

Revision Suggestion : Provide comment on reason why pull-in forces were not observed as expected, and different between WTC1 and WTC2.

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Report Number : NCSTAR1-6C
Page Number : 155
Paragraph : Section 6 Paragraph 1/Sentence 1 & bullet points
Comment : There appears to be no discussion on the relationship of the assumptions made for the size of the model, and the number of disconnected floors, to the observed/calculated interactions of the walls and the floors.
Comment Reason : Buckling failure of unrestrained columns with pull-in forces highlights the sensitivity of the interaction of floor structures and columns, and transfer of forces. The material in the report appears to be testing a range of conditions against column performance, without clearly relating them to actual patterns of damage either from the floor models or observation, so that failure loads can be determined.

Revision Suggestion : Provide discussion on the relationship of the assumptions made for the size of the model, and the number of disconnected floors, to the observed/calculated interactions of the walls and the floors.

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Report Number : NCSTAR1-6C
Page Number : 199

Paragraph : Chapter 7 paragraph 3 / sentences 1-2

Comment : It is noted that as described, the global models would not capture any effects resulting from the interaction of floors and columns, unless they are directly derived from the subassembly models or actual observations, and imposed on the global model as applied damage or forces. Hence it is important that all relevant bounds relating to the interactions between floors and vertical structure are explored at the level of the floor and other subassembly models.

There appears to have been no model in which floor structures, modelled in a way which captures their main actions, including thermal expansion, sagging, change of action from bending to bending/catenary, and support failure, can interact with the vertical structures over a number of storeys, if not the whole building. Hence it is of concern that some primary modes of building failure are reliant only on adjustment of the global models based on observation, rather than calculated interaction of the parts.

Comment Reason : Uncertainty in the effects of floor / wall interaction as modelled.

Revision Suggestion : Include more accurate floor models or state that this is a shortcoming and requires further research to justify collapse mechanisms.

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Report Number : NCSTAR1-6
Page Number : 121
Paragraph : Paragraph 2/Sentence 5
Comment : Two rates of damage estimates are selected per Tower from the analysis. These impact damage results are then used in the fire dynamics analysis, thermal analysis and the structural response analysis. However the report does not state what the criteria for damage assessment are, how they are set and evaluated. Would it be physical damage to the core columns, perimeter columns, facade or to where damage would have the largest effect on the structural fire performance of the towers?
Comment Reason : Because this analysis is the basis for all further analyses the assumptions, results and report should be as clear as possible.

Revision Suggestion : Report contents could be further clarified.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 121
Paragraph : Paragraph 4/Sentence 5
Comment : The statement that the effect of the fire proofing of the floor framing has limited effect on the structural fire behaviour should be supported by structural fire engineering analysis at elevated temperatures.
Comment Reason : Statement should be supported by calculations.

Revision Suggestion : Cross reference structural fire calculations which justify this statement.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 122
Paragraph : Paragraph 4/Sentence 2

Comment : It should be clarified how a comparison between the observed and predicted damage can be made. It is unclear what modes are analysed and how magnitudes are compared.

Comment Reason : It should be clarified how a comparison between analysis and observations are obtained. Mode and magnitudes should be explained in this section or references should be added to the text.

Revision Suggestion : A more detailed explanation of failure modes and magnitudes required.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 124

Paragraph : Paragraph 1/Sentence 5

Comment : The column fire behaviour would be affected by visible local distortions of the column cross section (e.g local flange bending).

Specifically restrained thermal expansion effects and rotations at connections would further reduce the capacity of the column in fire.

Comment Reason : The core column structural fire behaviour could have had a major impact on the global behaviour of the WTC towers. These assumptions could have had a major effect on the global behaviour and even collapse sequence of the tower. It is suggested that the column strength / buckling capacity of moderate damaged columns could have been modified to better represent the damage in the global model.

Revision Suggestion : Please explain why retaining moderately damaged core columns without modification are believed to be reasonable.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 129
Paragraph : Paragraph 7/Sentence 1

Comment : It should be explained why it is conservative to ignore large parts of fire protection being dislodged in determining the structural fire behaviour of the towers. It is unclear why damage to fire protection due to vibrations in the building is not investigated, since the presence of fire protection material is a critical factor in the global structural fire analysis.

Comment Reason : The fire behaviour is mainly driven by thermal expansion and material degradation at elevated temperatures and our main concern is more steel is cool than may have occurred and this is not conservative for a failure analysis.

Revision Suggestion : Explain how this estimation is conservative in the report.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 130

Paragraph : Paragraph 1/Sentence 3-9

Comment : It should be explained why damage to fire protection due to the impact of jet fuel is not investigated, since the presence of fire protection material is a critical factor in the global structural fire analysis.

Comment Reason : The fire behaviour is mainly driven by thermal expansion and material degradation at elevated temperatures and therefore an accurate estimation of heating to structural elements is crucial to get reliable and realistic results.

Revision Suggestion : Explain how this estimation is conservative in the report.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 186
Paragraph : Section 7.2.2
Paragraph 2/Sentence 4
Comment : The report should state if Case A impact damage and Case B temperature history happen at the same time?

Comment Reason : If they do not happen in the same event, what is the physical meaning for combining these two together. Even if the result showed better correlation with the real case, it did not represent the real structural behavior.

Revision Suggestion : Clarification needed.

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 192
Paragraph : Section 7.3.1
Paragraph 1/Sentence 5

Comment : It is not clear how the strain of the concrete was modelled, especially for the tension zone?

Comment Reason : The report mentioned that the concrete material model used the compressive strength as the yield point, with the same yield strength in both tension and compression. It is not clear how the strain of the concrete was modelled. Was the strain of concrete in the tension zone the same as the bilinear stress-strain constitutive model assumed for the compressive zone, in which case it is not considered as an appropriate material model for simulating concrete behavior.

Revision Suggestion : Provide detailed clarification of concrete model.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 209
Paragraph : Section 7.4.1
Paragraph 6/Sentence 1
Comment : Inward pull in forces were estimated based on trial and error procedures to match photos.

Comment Reason : Simply showing a good comparison with the observation is not enough for this highly complex problem and can not prove the assumptions made about the pulling forces.

Revision Suggestion : A full non-linear analysis with thermal expansion and non-linear inelastic material properties is the only way to justify the estimated magnitude and distribution of the pulling forces. Further research projects may need to be proposed.

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 221
Paragraph : Section 7.5
Paragraph 3/Sentence 1
Comment : Justification needed.
Comment Reason : For a 60ft span beam, the thermal expansion at 200C will be larger than the elongation caused by the floor sagging of 25in. Therefore, it could be in compression due to restrained thermal expansion, not in tension.

Revision Suggestion : Greater justification for inward pull forces is required.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 170
Paragraph : Paragraph 4-6
Comment : An elastic super element to model the hat truss of WTC 2 is of concern.
Comment Reason : We would have thought that it would become inelastic near failure if this is a key load carrying path.
Load transfer via the hat truss is captured by the WTC1 model but as super elements were used in WTC 2 accuracy in any load transfer near failure is difficult to justify.

Revision Suggestion : Repeat analysis or flag as a research study for the future.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 165
Paragraph : Paragraph 1, Sentence 1-2
Comment : Incorporating trusses in the floor slab as a smeared model is of concern.
Comment Reason : Incorporating trusses in the floor slab as a smeared model is of concern.

Revision Suggestion : Repeat analysis with trusses modelled explicitly or flag as a research study for the future.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 170
Paragraph : Paragraph 2-3

Comment : It is of concern that thermal expansion is not included in the floors of the main models.

Comment Reason : As modelled the floors cannot be expected to push or pull on the columns as they expand and bow in the real fire. This means the real structural response in fire is not captured.

Revision Suggestion : Repeat analysis with thermal expansion included or flag as a research study for the future.

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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 170
Paragraph : Paragraph 1/Sentence 1-5
Comment : It is of concern that the axial degree of freedom was released on the spandrels because visual inspection showed that buckling of the spandrels played little role in the collapse sequence.
Load transfer via vierendeel action along the length of the exterior walls may have been affected by the omission of the spandrel beams this needs to be justified. This would be of more importance if wind load had been included.

Comment Reason : They could play a significant role in load transfer along the column walls therefore the force distribution in the model.

Revision Suggestion : Justify omission in context of load transfer during the fire.

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Information Submitted on: 8/3/2005.

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Report Number : NCSTAR1-6D
Page Number : 170
Paragraph : Paragraph 2-3

Comment : It is of concern that thermal expansion is not included in the floors of the main models.

Comment Reason : As modelled the floors cannot be expected to push or pull on the columns as they expand and bow in the real fire. This means the real structural response in fire is not captured.

Revision Suggestion : Repeat analysis with thermal expansion included or flag as a research study for the future.

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Information Submitted on: 8/3/2005.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 170
Paragraph : Paragraph 1/Sentence 1-5
Comment : It is of concern that the thermal expansion of the spandrels was set to zero.
Comment Reason : Any forces generated as a result of this expansion are not calculated by the model. This will effect overall structural response to fire during the fires when loads are transferred via the exterior walls.
Revision Suggestion : Justify omission in context of load transfer during the fire.

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 164

Paragraph : Paragraph 5/Sentence 2-4

Comment : It is of concern that only mechanical floor beams and core beams with moment connections were included in the main models. The justification given for this is that simple beams cannot transfer shear to columns at their connections.

Comment Reason : This is not strictly true and shear will be transferred if the beam is connected to a column. In reality moment can also be transferred because connections will have some moment capacity even if it has been ignored in design. By omitting beams in the core the gradient in the composite core slab thus the forces as a result of thermal expansion effects on the rest of the structure are not modelled. It is assumed the columns provided with some form lateral support where a beam is omitted else the slenderness of the column is too high in the models.

Revision Suggestion : Repeat analysis with all beams in the core at least in sub-model or flag as a research study for the future.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 164
Paragraph : Paragraph 4/Sentence 4-5
Comment : In reality the material properties of plates 1 and 2 versus plate 3 of a typical exterior column are different however in the models they were assumed to be the same. This has not been justified.
Comment Reason : It is not clear from the report if this assumption affects the outcome of the modelling process.

Revision Suggestion : Justify assumption.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Report Number : NCSTAR1-6D
Page Number : 171
Paragraph : Paragraph 2-3

Comment : It is of concern that the outriggers of the hat truss were increased in size in the WTC1 model to account for the incorrect increase in compressive stresses when the construction sequence was not considered.

Comment Reason : This could make the models non conservative because the loads in the hat truss during the fire will be very different to the loads at ambient regardless of how stressed the hat truss was originally.

Revision Suggestion : Justify decision by looking at the response of the hat truss to the load redistribution during the fires in WTC1 with and without this increase in member size.

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 7
Paragraph : Paragraph 1/Sentence 1-4
Comment : There is no mention of wind load applied to the 3D structural fire models of the towers. It is of concern if this has not been considered.
Comment Reason : Given the height and impact of wind on the frame a sensitivity study should have been carried out to quantify the impact of wind and omit if justified.

Revision Suggestion : Do sensitivity study or apply to global model and repeat analysis.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Report Number : NCSTAR1-6D
Page Number : 7

Paragraph : Paragraph 1/Sentence 1-4

Comment : The report states that 25% of the design live load is applied to the models but there is no justification given as to why this value was chosen. Is this based on survey data of the actual building or an assumption if so how is it justified?

Comment Reason : Of interest to the reader why this value was chosen.

Revision Suggestion : Justify or explain the use of 25% of the live load.

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Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 22
Paragraph : Paragraph 2/Sentence 6
Comment : The report states that gravity load was not applied to the floors but it is not clear if live load was applied or whether this was only to the columns. Was live load applied to the columns only?
Comment Reason : If live load was not applied to the floors then there is no load at all applied to the floors therefore no pull-in force applied to the columns as a result of this.

Revision Suggestion : Clarify and justify decision.

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Information Submitted on: 8/3/2005.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 165
Paragraph : Paragraph 1-2

Comment : It is of concern that the concrete floors with smeared model included to model the trusses are fully elastic with the same strength in compression and tension.

Comment Reason : This ☐elastic☐ property approach allows the floors to carry significant tensile loads in membrane action. This approach was used 15 years ago in very early models of the Cardington tests in the UK when convergence problems were an issue. This was then justified because the building was not near impending failure. Later models used accurate damage plasticity models to represent the concrete. An elastic floor model is not a reliable method of modelling a slabs response to fire particularly near failure when tension forces should not be allowed to develop to unrealistic levels.

Revision Suggestion : Repeat analysis with full inelastic material properties or flag as a research study for the future.

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Information Submitted on: 8/3/2005.

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Report Number : NCSTAR1-6D
Page Number : 6
Paragraph : Paragraph 1/Sentence 4
Comment : It is clear that NIST have spent significant time and effort modelling creep. They have been able to extract creep strains separately from the mechanical strains calculated by the ANSYS models therefore it is assumed that the model includes creep explicitly.
Has the creep model and its effects been tested as part of a sensitivity study of load, temperature and section size on simple single beams or columns? How was it validated?

Comment Reason : Validation is important for new modelling techniques.

Revision Suggestion : Conduct simple sensitivity study to understand the effect of creep on a single heated element.

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Report Number : NCSTAR1-6D
Page Number : 31

Paragraph : Paragraph 3/Sentence 4-6

Comment : The exact details of how the simplified temperature distribution was established are not clear and it would be useful if the simplified temperature data was explained in diagrammatic form for comparison with the real gradients and temperature distributions in the structure.

Comment Reason : For comparison so the reader can understand if it was reasonably accurate or overly simple.

Revision Suggestion : Show the simplified temperature data in diagrammatic form for comparison with the real gradients and temperature distributions in the structure.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 31
Paragraph : Paragraph 3/Sentence 4-6
Comment : It is not clear how the simplified temperature-time data at 10 minute intervals compares with the predicted temperature-time data at many points.
Comment Reason : The reader should be able to understand if the 10-minute interval plots were reasonably accurate or overly simple compared with the actual predicted temperatures.

Revision Suggestion : Generate graphs of the actual temperature-time data with the simplified model data at 10 minute intervals superimposed on top to clarify this concept for the reader.

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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR1-6D
Page Number : 36/48

Paragraph : Paragraph 1-2/Paragraph 3

Comment : It is of concern that the amount of thermal bowing on the columns is highly dependent on the pull-in force applied which was arrived at by applying different forces in a trial and error approach until the bowing in the model matched the pull-in observed by the video footage.

Comment Reason : Clearly the impact of thermal expansion was considered important for the columns and in the floors/trusses in the sub-assembly models but due to convergence problems was omitted from the floor system (trusses and slab) in the main 3D models of WTC 1 and 2. Consequently, the pull-in forces on the columns from the floors were estimated by a trial and error approach to match bowing of the columns from visual evidence in videos and photographic footage. This force was not calculated by modelling. Moreover, by ignoring expansion in the floors of the 3D model the push force from the expanding floors on the columns in the earlier stages of the fire was also ignored. The time dependent change of □pull or push□ force on the columns has not been captured and this is critical to the structural response thus eventually the collapse mechanism proposed.

Revision Suggestion : Include thermal expansion in the floors and repeat analysis.

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Name : Barbara Lane
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Report Number : NCSTAR1-6D
Page Number : 36/48
Paragraph : Paragraph 2/Paragraph 3
Comment : No push-out forces are ever applied to the columns which would represent the floors expanding.
Comment Reason : This is critical to the structural response thus eventually the collapse mechanism proposed.

Revision Suggestion : Include thermal expansion in the floors and repeat analysis.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

In

Page 1 of 1

From: Barbara Lane <barbara.lane@arup.com>
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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 57
Paragraph : Paragraph 1/Sentence 1
Comment : There is no justification for the extent of the wall model chosen.
Comment Reason : It is of interest to the public why 9 storeys was chosen and if this can be justified.

Revision Suggestion : Justify decision.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Report Number : NCSTAR1-6D
Page Number : 304
Paragraph : Paragraph 2

Comment : The key responses described by NIST as the events which lead to collapse are all plausible when considered qualitatively i.e. sagging of floors, pull-in of columns, load transfer, weakening of the core. The validity of the collapse mechanism cannot be proven.

Comment Reason : The collapse mechanism proposed is one possible mechanism only but the reasoning and calculation of the pull-in forces which contribute to the collapse are not justified nor validated. The load transfer and column response are calculated in response to ☐made-up☐ forces from the floors therefore the values of strain, stress etc calculated by the models are not useful as a quantitative assessment.

Revision Suggestion : Include thermal expansion in the floors, model trusses explicitly with thermal expansion also, use a full inelastic model for the concrete floor and repeat analysis.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 333
Paragraph : Paragraph 2

Comment : Of greatest concern is the removal of the strap anchors as this prevents the columns being loaded by the expanding and sagging floor therefore horizontal reaction forces experienced by the columns are not accurately distributed. The removal of the bridging trusses also changes the restraint to thermal expansion of the perpendicular trusses and the slab therefore also introducing errors to the calculation.

Comment Reason : The inadequacy of the single floor model to calculate pull-in forces further emphasises the need to calculate it in the global model.

Revision Suggestion : Include thermal expansion in the floors, model trusses explicitly with thermal expansion also, use a full inelastic model for the concrete floor and repeat analysis.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6D

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6D
Page Number : 349
Paragraph : Paragraph 1/Sentence 12-13
Comment : It is of concern that the single floor models showed push-out of the columns but that this was not modelled in the global models.
Comment Reason : A key force on the columns is not modelled in the global model.

Revision Suggestion : Include thermal expansion in the floors, model trusses explicitly with thermal expansion also, use a full inelastic model for the concrete floor and repeat analysis.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 272
Paragraph : Paragraph 4

Comment : Of concern is the fact that multiple floor fires have not been considered on an undamaged model without impact therefore the conclusions are not justified. Evidence from research being carried out by Arup suggests that multiple-floor fires could result in collapse of structures comprised of long span floor systems similar to WTC and other forms of construction. Moreover, burnout of the compartment in 20 minutes seems short and it is known that multiple floor fires can burn at relatively low temperatures for many hours, for example the Madrid Torre Windsor Fire, Spain, 2005, continuously heating protected steel and concrete reducing the effectiveness of thermal lag and weakening the structure.

Comment Reason : The most likely reason that the structure would survive a multiple floor fire is that in an undamaged building the core would not be heated therefore this alternative load path via the hat truss for load from the exterior columns would remain sufficiently strong for the duration of a fire and could have prevented collapse. This not modelled by a single floor model.

Revision Suggestion : Include thermal expansion in the floors, model trusses explicitly with thermal expansion also, use a full inelastic model for the concrete floor in the global models and repeat analysis without impact damage.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

In

Page 1 of 1

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 286
Paragraph : Bullet Point 1

Comment : In Section 9.3, floor sagging is attributed to the steel temperatures as a result of loss of fire proofing, yet it is well documented that protected steel can be subject to sagging, in fire events.

Comment Reason : Protected steel can be subject to sagging also.

Revision Suggestion : Change text to explain that floor sagging can be a result of a number of factors and unprotected steel is only one.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 312
Paragraph : Bullet Point 6

Comment : Whilst we agree the Towers did not collapse solely due to impact, we do not agree with NIST's conclusion that only impact induced fire proofing damage caused the collapse.

Comment Reason : In the event of a multiple floor fire, protected structure heats (as it does in a single floor fire), and this heating of columns over multiple floors causes thermally induced structural responses, which could lead to collapse. Loss of fire proofing may have reduced the time to collapse, but the analysis presented in Project 6 does not prove that it would have prevented collapse, particularly when so much emphasis is placed, in this regard, on the tests carried out.

Revision Suggestion : Alter report conclusions to reflect this.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 311
Paragraph : Paragraph 3/Sentence 2-3
Comment : NIST correctly observe the loss of strength and stiffness attributed to temperatures in the region of 500-600°C> However they do not mention that thermal expansion effects occur in structures at temperatures as low as 100°C. Therefore even for their stated protected structural elements not exceeding 400°C, we would expect to see serious thermally induced structural response, particularly if such temperatures occurred over multiple floors.
Comment Reason : Thermal expansion effects occur in structures at temperatures as low as 100°C.

Revision Suggestion : Change text to explain that thermal expansion occurs at temperatures < 400C.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 311

Paragraph : Paragraph 4/Sentence 3-4

Comment : We disagree that only without fire proofing does floor sagging occur to the extent possible to exert pull-in forces on the wall. In addition NIST do not mention the outward lateral expansion of the columns that could occur at temperatures in the region of 400°C, before inward bowing would occur. In addition we disagree that load distribution would be negligible had the fire proofing remained in place, and that the towers would remain stable.

Comment Reason : Floor sagging, push and pull-in of columns by the heated floors occurs even when steel protected.

Revision Suggestion : A global multi-floor model analysis with accurate time dependent material properties, thermal expansion and full representation of the trusses but without impact damage should be carried out before this current conclusion, of critical importance, that only loss of fire proofing due to impact resulted in the collapse of the Towers.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 311

Paragraph : Paragraph 6/Sentence 1-2

Comment : It is of concern that the standard test data has been used as proof that had the fireproofing remained in place no structural response would have occurred.

Comment Reason : We believe the single element test can not replicate the complex multiple element structural system in the Tower, the effects of restrained thermal expansion, and resulting fire-induced load bearing mechanisms, and this concept is well accepted in the structural fire community.

Revision Suggestion : State limitations of test and justify conclusion as a result of whole frame modelling not testing.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR 1
Page Number : 204

Paragraph : Paragraph 3/Bullet 4

Comment : We do not support the concept of preventing local failure in an unsprinklered fire as this should have no impact on life safety in a building with an implemented evacuation plan for both occupants and emergency responders.

Comment Reason : Local failure can in fact relieve thermally induced forces and so may help prevent a progressive collapse mechanism. Such over - design in our view would not greatly enhance the overall building response to the fire.

Revision Suggestion : Reconsider the issue of design for local failure or define clearly what local failure is? Buckling of a beam is good for the structure therefore should not be designed against.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR 1
Page Number : 204
Paragraph : Paragraph 3/Bullet 5

Comment : We do not understand how a window assembly could ever be detailed to guarantee prevention of failure in a severe fire event.

Comment Reason : From a structural robustness perspective we would prefer to detail the structure to withstand such an event, rather than rely solely on prevention of glazing failure. This form of prevention we would consider to be a serious weakness in the design package.

Revision Suggestion : Omit or revise recommendation.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
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Report Number : NCSTAR 1
Page Number : 205

Paragraph : Paragraph 2/Sentence 2

Comment : Recommendation 5 is of concern.

NIST recommends that the technical basis for the century-old standard for fire resistance testing of components, assemblies, and systems should be improved through a national effort. Necessary guidance also should be developed for extrapolating the results of tested assemblies to prototypical building systems.

We support NIST's call for improved evaluation of untested building elements; as well as the relationship between prescriptive ratings and performance of assemblies in real fires.

Comment Reason : The standard fire resistance test provides an excellent comparative test to understand the relative performance of products in the construction industry. It does not attempt to quantify real structural response to fire, nor the factors NIST have identified as significant to now understand, particularly the role of long span systems in fire. The lack of identification by NIST of the role of thermal expansion here is a concern.

Revision Suggestion : The knowledge NIST recommends as now being required, can only be gained from full-scale structural testing or thermo-mechanical analysis of structural systems and frames in fire.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
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Report Number : NCSTAR 1
Page Number : 207
Paragraph : Paragraph 2/Sentence 2
Comment : Recommendation 7 is of concern.
NIST recommends the nationwide adoption and use of the □ structural frame □
approach to fire resistance ratings.

Comment Reason : We would recommend that full frame structural fire analysis provides the most robust form of determining weakness in structural designs for fire, particularly when multiple floor fires are a real concern. We recommend that a move towards specific structural detailing to prevent structural collapse mechanisms in fire be the future of tall building design, rather than increasing reliance on passive fire protection.

Revision Suggestion : Make changes to the recommendation where possible to reflect our concern.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR 1
Page Number : 207
Paragraph : Paragraph 4/Sentence 2
Comment : Recommendation 8 is of concern.
NIST recommends that the fire resistance of structures should be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without local or global collapse.

Comment Reason : The concept of non-operation of sprinklers is significant should a risk based assessment deem it necessary to consider in a structural design only. We do not however support the concept of design to limit local collapse but do to prevent global collapse, as it is not clear why this level of over design would be merited, except for some very specific and rare events.

Revision Suggestion : Suggest that the concept of preventing local collapse is qualified with the following statement, ☐ unless such collapse leads to an overall/progressive collapse, or compromises the integrity of required primary routes for egress and emergency services access ☐.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

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Report Number : NCSTAR 1
Page Number : 207

Paragraph : Paragraph 5/Sentence 2

Comment : Recommendation 9 is of concern. NIST recommends the development of:
(1) performance-based standards and code provisions, as an alternative to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse; and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the structure as a whole system.

Comment Reason : We disagree with the concept of preventing local collapse. We would also point out that tools already exist to assess structural response to fire, and would benefit from increasing validation for the increasing number of structural systems available. It is not clear if NIST support retrofit of all structures, which seems an unrealistic concept.

Revision Suggestion : It is not clear what form of testing could ever standardise this approach as it is not possible to re-create fires as a standardised event in building and so we would suggest alternative means of validating performance based design for structures in fire.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR 1
Page Number : 80
Paragraph : Paragraph 1/Sentence 2-3
Comment : It is not clear where NIST have presented their formal statistical methods to identify those parameters that had the greatest effect on the model output (page 80).

Comment Reason : Methods used, assumptions and results of interest to researcher, consultants etc.

Revision Suggestion : Provide details of where this information is presented and access for review.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
Cc: dlowe@nist.gov
Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR 1
Page Number : 87
Paragraph : Paragraph 2
Comment : NIST should present the values used in the structural fire models for specific heat, thermal conductivity and coefficient of thermal expansion.

Comment Reason : In order that researchers can repeat work if interested and reviewers can check validity of the models.

Revision Suggestion : Provide details of where this information is presented and access for review.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

In

Page 1 of 1

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Report Number : NCSTAR 1
Page Number : 101
Paragraph : Phase 3

Comment : We strongly disagree with NIST's repeated statement that disconnection of the spandrels and use of equivalent thickness slabs (incorporating the concrete slab and truss in the same model plate finite elements) in tenant areas had little influence on the global collapse initiation □ this in our opinion is one of the key parameters contributing to the global failure.

Comment Reason : We disagree with NIST's statement.

Revision Suggestion : Revise statements if possible.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR 1
Page Number : 117
Paragraph : Paragraph 4

Comment : On page 117 Section 6.9.3 NIST raise the interesting point that in areas not affected by debris the SFRM was dislodged from perimeter columns □ has it been investigated if this in fact means some columns were entirely unprotected in the as-built condition? Or is it the case that the bonding was so poor that the material fell off relatively easily on about 67% of the steelwork.

Comment Reason : Of interest.

Revision Suggestion : State in the report the reason for the exterior columns being unprotected or best guess at reason.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR 1
Page Number : 139
Paragraph : Paragraph 2
Comment : It remains a serious concern that the fact even low temperatures can cause thermal expansion appears to be not considered as significant in the report and was therefore likewise not reflected in the global models. In Section 6.12.6 again the role insulation played in keeping temperatures low even in the vicinity of a fire is emphasised. However it is well documented that protected steel also undergoes thermal expansion and therefore affects the overall frame response. How was this incorporated therefore in the global models when determining the collapse behaviours?

Comment Reason : We believe the repeated statements about fire protection are a little mis-leading.

Revision Suggestion : Address the issue that protected steel expands and explain the importance of this throughout all reports.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

Information Submitted on: 8/3/2005.

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Phone : +44 (0)207 755 3303
Report Number : NCSTAR 1
Page Number : 144
Paragraph : 2nd last bullet point
Comment : Again, in Section 6.14.4 the role thermal expansion played in the early stages of the fire is identified here. It is very difficult to conclude therefore what exact role NIST believe thermal expansion effects had on the overall stability of the structural systems. In addition the loss of strength is repeatedly stated as the critical behaviour and the result of high temperatures, yet we would contend that thermal expansion is the governing behaviour.
Comment Reason : It is unclear the importance NIST place on thermal expansion.

Revision Suggestion : Confirm exact role that thermal expansion had if the behaviour of the towers and be consistent throughout report.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
To: wtc@nist.gov
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR 1

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Report Number : NCSTAR 1
Page Number : 145

Paragraph : Section 6.14.4 last 3 bullets in this section

Comment : Probably the most important conclusion in the NIST report is their belief that had the insulation not been removed by impact, collapse would not have occurred. In other words had there been as serious multiple floor fire collapse would not have occurred. It has not, in our view, been quantified in anyway through the structural fire models presented to date, how NIST have reached this conclusion. Particularly when the role of thermal expansion of the floor systems, which in multiple floor fires can trigger failure, has not been included in NIST's models.

Comment Reason : We are concerned that this conclusion cannot be adequately justified

Revision Suggestion : Modify conclusion to take into account the shortcomings of the modelling approach

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
Affiliation : Arup Fire
Email Address : barbara.lane@arup.com
Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 314
Paragraph : Section 10.3, Paragraph 1/Sentence 3
Comment : The average SFRM thickness based upon a limited set of measurements does not necessarily represent the entirety of these very large buildings. Therefore, it is not valid to consider the average value to be the as-applied thickness, especially since it does not represent the critical (minimum) thickness observed.
Comment Reason : Clarification needed.

Revision Suggestion : Replace "as applied" with "average"
Include discussion regarding the justification and impact of using the average SFRM thickness.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

From: Barbara Lane <barbara.lane@arup.com>
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Information Submitted on: 8/3/2005.

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Report Number : NCSTAR1-6
Page Number : 318
Paragraph : Paragraph 3
Comment : We request clarification and quantification of how the lack of inward bowing of the west face contributed to the time to collapse, and probable collapse mechanism.
Comment Reason : We do not understand this aspect of finding 28.

Revision Suggestion : Clarify and quantify how the lack of inward bowing of the west face contributed to the time to collapse, and probable collapse mechanism.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Report Number : NCSTAR1-6
Page Number : 321
Paragraph : Paragraph 6
Comment : Finding 52: We agree with finding 52 but the floors also pushed the columns out and provided support to the columns in their weakened, deflected form. This was not captured by the models and is of concern.
Comment Reason : Structural behaviour for the duration of the design fire is not modelled properly as a result of shortcomings in the floor model.

Revision Suggestion : Model the concrete floors with inelastic properties, thermal expansion and include the trusses explicitly therefore calculate the true role of the floors on the behaviour.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 321
Paragraph : Paragraph 7
Comment : Finding 53: Noted. Arup models with thermal expansion and inelastic properties included have shown that very little lateral support is required by the columns from the floor therefore even when highly weakened and deflected the floors play an important role.
Comment Reason : This finding is difficult to justify because it still relies on the accuracy of the floor models which is flawed as a result of elastic properties, no thermal expansion and no trusses included.

Revision Suggestion : Model the concrete floors with inelastic properties, thermal expansion and include the trusses explicitly therefore calculate the true role of the floors on the behaviour.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Subject: WTC Draft Final Report Comment Form for Report: NCSTAR1-6

Information Submitted on: 8/3/2005.

Name : Barbara Lane
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Phone : +44 (0)207 755 3303
Report Number : NCSTAR1-6
Page Number : 322
Paragraph : Paragraph 2
Comment : Finding 55: This statement is plausible and could be true but is not adequately justified by the models used.
Comment Reason : This finding is difficult to justify because it still relies on the accuracy of the floor models which is flawed as a result of elastic properties, no thermal expansion and no trusses included.

Revision Suggestion : We would suggest that a study of the quantity of outward and inward bowing columns in WTC 2 relative to WTC 1 could provide an interesting theme with respect to understanding time to collapse of each Tower. In addition creating a multiple floor model with full inelastic properties, thermal expansion of the floors fully included and allowed to change with time would also assist in understanding the time to collapse, and the various possible probable collapse mechanisms in a Tower of this structural form. Such a study would also greatly benefit future design guidance for tall buildings in severe fire events.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005

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Information Submitted on: 8/3/2005.

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Paragraph : Paragraph 3/ Sentences 1

Comment : It should be explained why it is conservative to ignore large part of fire protection being dislodged in determining the structural fire behaviour of the towers. It is unclear why damage to fire protection due to vibrations in the building is not investigated, since the presence of fire protection material is a critical factor in the global structural fire analysis.

Comment Reason : Fire behaviour is mainly driven by thermal expansion and material degradation at elevated temperatures and our main concern is more steel is cool than may have occurred and this is not conservative for a failure analysis.

Revision Suggestion : Explain how this estimation is conservative.

2005 WTC Report Comment Application 1.0, dlowe@nist.gov, rev. 6/21/2005